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Title: Three New Lead (Pb) Benchmark Experiments Performed Using Plutonium and Different Enrichments of Uranium

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Three New Lead (Pb) Benchmark Experiments Performed Using Plutonium and Different Enrichments of Uranium

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Three New Pb Experiments

- Over the past four years we have performed three experiments containing lead.
  - HEU/Pb
  - “LEU”/Pb
  - Pu/Pb
- In addition to finding critical configurations, lead void reactivity worth measurements were the focus.
- These have been performed in collaboration with JAEA and with funding from the NA-232 Office of Nuclear Material Removal.
- All experiments were performed on the Comet critical assembly.
  - Main activity on Comet over the past 4 years in addition to KRUSTy.

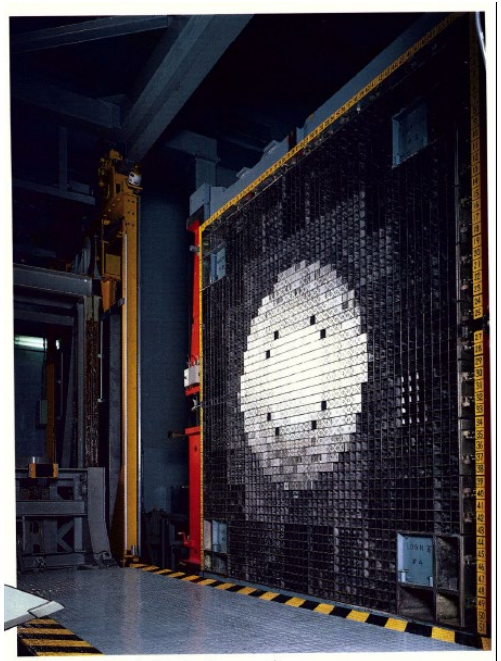
Benchmark Evaluations

- To preserve the valuable data generated in this evaluation we are preparing evaluations for the ICSBEP Handbook
- Evaluations prepared by:
  - Kelsey Amundsen, DNFSB intern at UC Berkley - HEU/Pb
  - Akito Oizumi, Researcher at JAEA FCA - “LEU”/Pb
  - Alex McSpaden, LANL NEN-2 R&D Engineer - Pu/Pb

Fast Critical Assembly (FCA) in Japan

FCA did not returned to operation following the 2011 tsunami

- Accelerated shipping schedule returned HEU and Pu fuel for FCA to US under Remove Program.
- Many planned experiments in support of an accelerator driven system to transmute minor actinides (Np, Am, Cm) could not be performed.
- HEU and LEU cores were planned to emphasize differences in Pb cross sections at energy above 1 MeV.
- Lead void measurements are important for regulatory approval of system with lead-bismuth coolant.

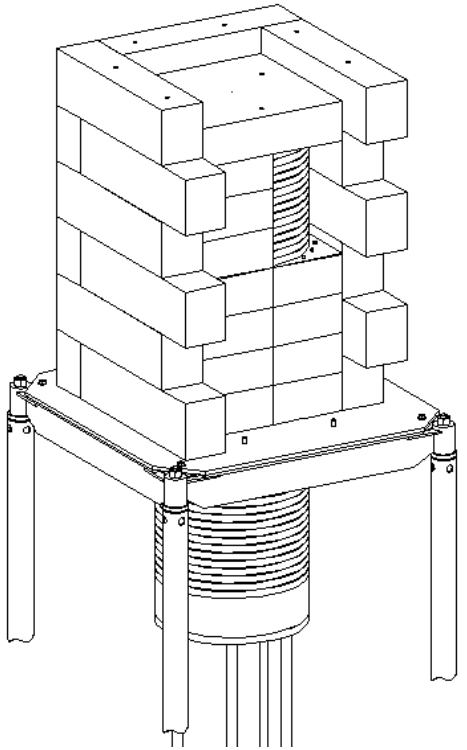


固定側½集合体密着面(51行×51列)

Cross section of fixed half assembly (51 by 51 tubes)

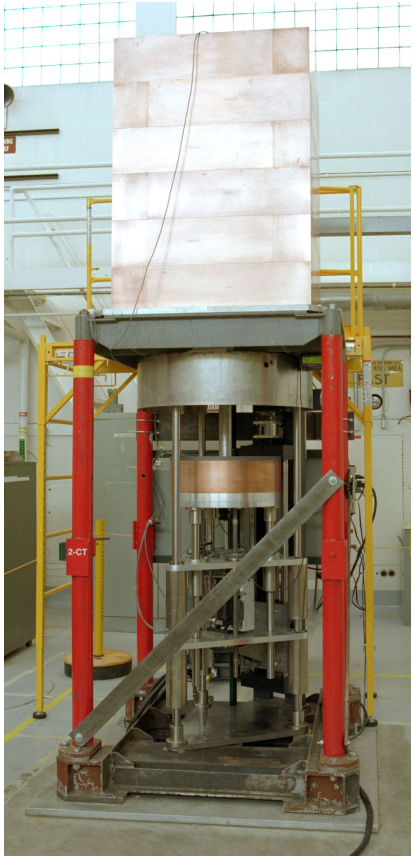
National Criticality Experiments Research Center (NCERC) in Nevada

- Experiments at NCERC were designed to produce comparable data for JAEA
- Comet is a Vertical Assembly Machine used for the entire series of experiments
- Lower fuel is placed on moveable platen and lifted towards a stationary upper fuel stack
- JAEA researchers visited NCERC to observe and record data

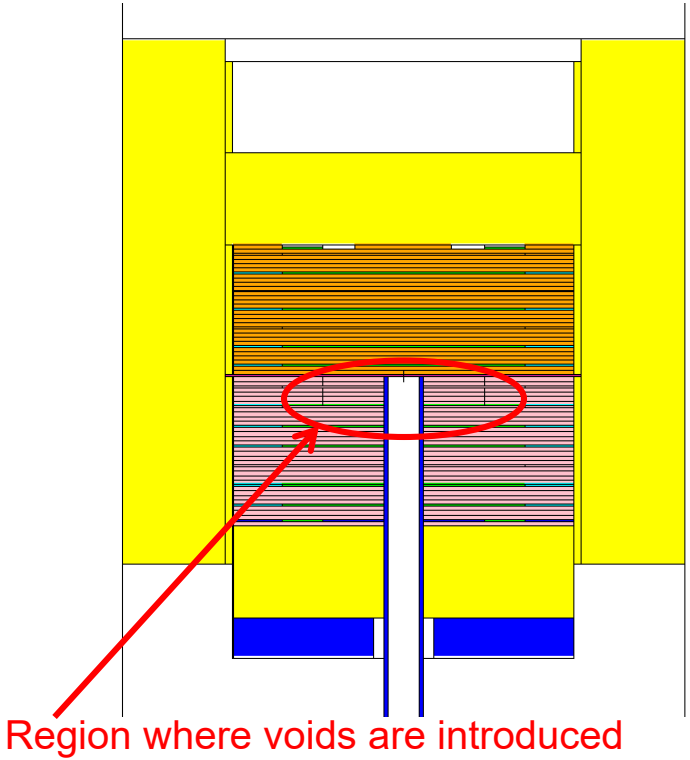


Summary of NCERC Experiments

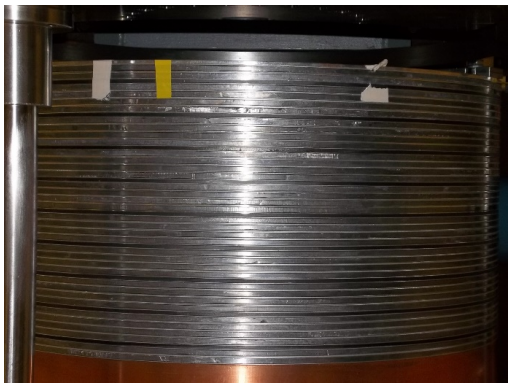
- Zeus Series of Experiments
  - Copper reflector
  - HEU fuel
  - Various interstitial materials (graphite, iron, poly) to modify spectrum
  - Used lead as the interstitial for first JAEA exp
- Expanded Zeus Series to include NU
  - Allowed an “LEU” core to be created
  - Alternating NU and HEU with lead interstitial
- Designed Jupiter Experiment
  - Used ZPPR Pu plates and lead



HEU/Lead Core

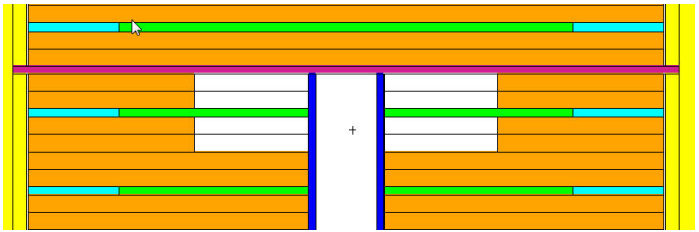


- Pb sandwiched between Al plates not glued
- 9 units below, 6 above
- Focused on 6V and 8V cases
- New Al spacers: mass matches mass of Al removed with Pb



HEU/Lead Void Experiments

HEU core (not to scale)
Void is 10” diameter



green/blue=HEU
orange=lead
yellow=copper
magenta=steel
blue=aluminum

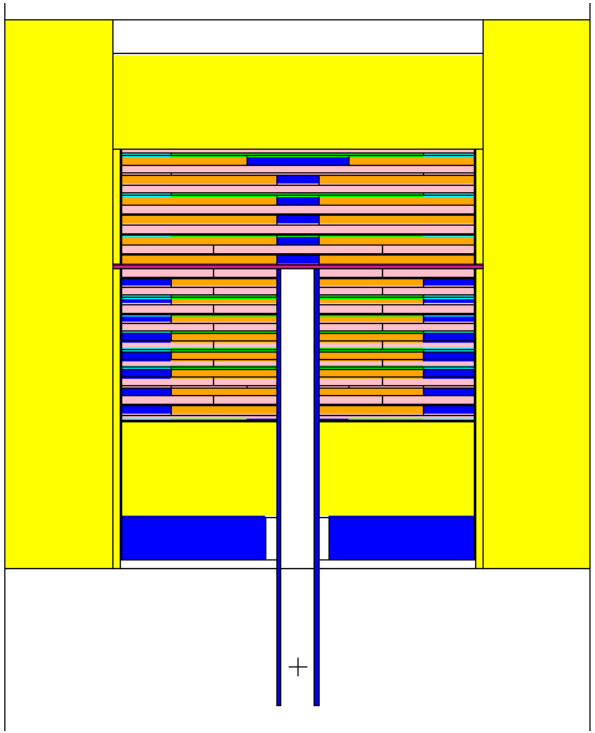
Removed lead to measure change in reactivity

2V—One void above and one void below U plate.

4V—Void above and below two U plates.

Void with aluminum piece (Al spacer mass equal to Al plates removed with Lead)

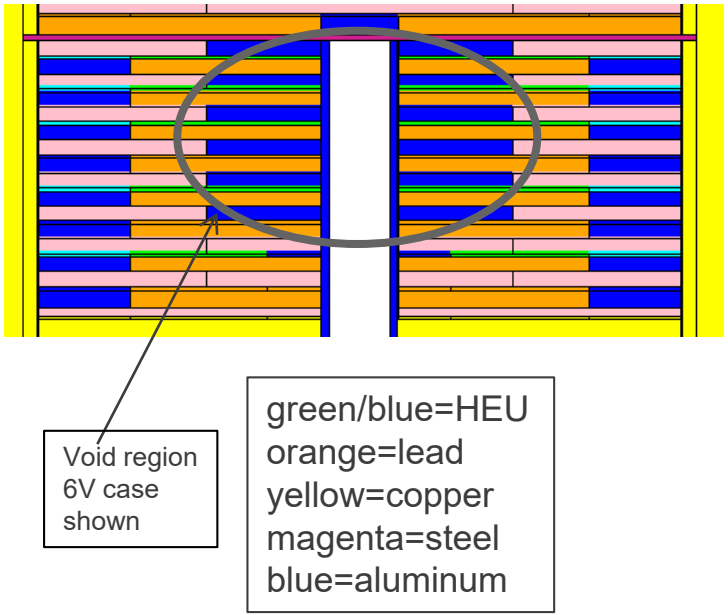
LEU/Lead Void Experiments



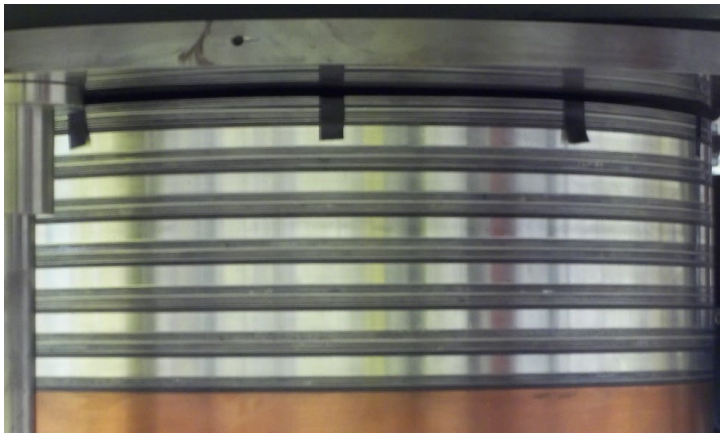
LEU core (to scale)

- Natural uranium plates alternating with HEU plates
- Effective enrichment ~21%
- Similar measurements to HEU core
- Some NU plates surrounded by Al rings to reduce weight
- Positive Void Coefficient (HEU system has negative coefficient)

LEU Core Lead Void Experiments



- LEU Core
  - Void with aluminum spoked spacers
  - One Void equals 2 lead plates (half as many as HEU core)

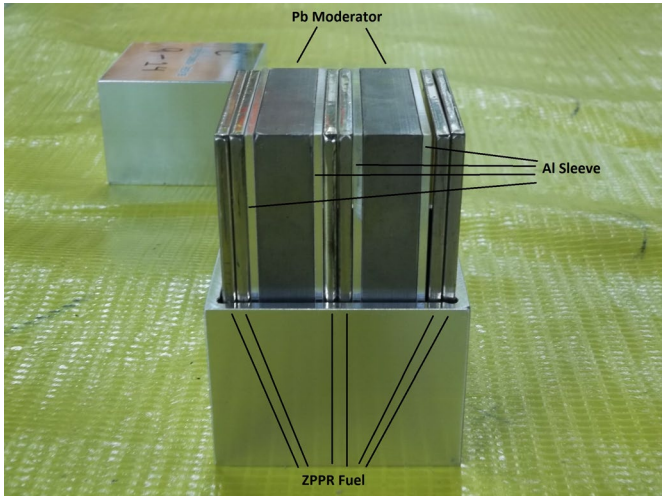


Plutonium/Lead Experiments: Unit Cell

PU06 Unit Cell:

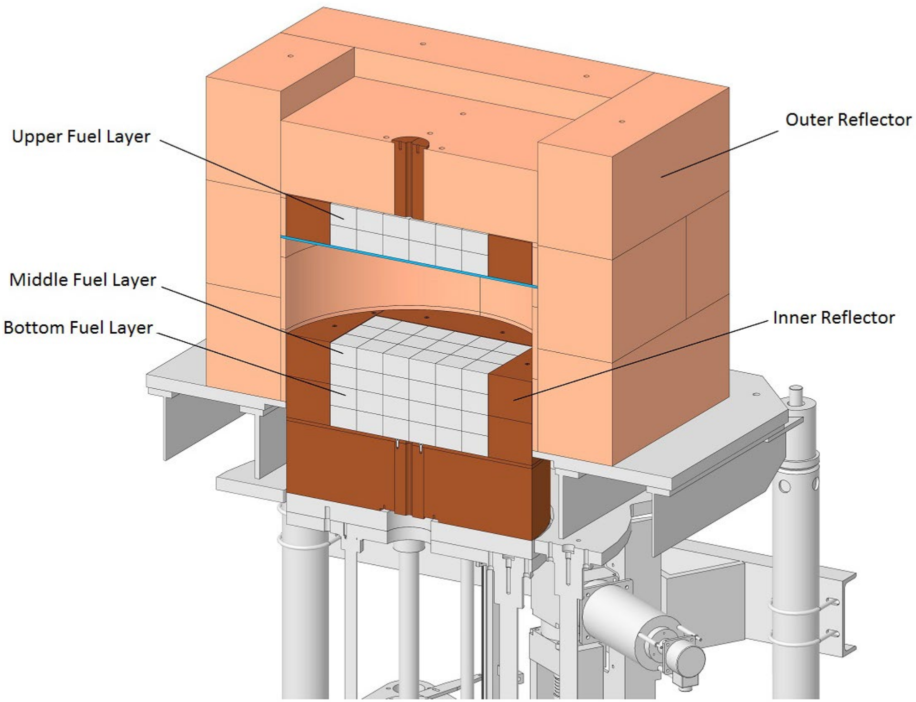
dark blue=Pu; green= ZPPR cladding; orange= lead; turquoise= Al frame/ box; red= copper

- Comet with ZPPR fuel and Cu reflector
  - Welded nickel-plated stainless steel
  - 3” x 2” x 0.25”
  - All configurations are much smaller than FCA.



Array of Box Units

- One layer on the stationary upper platform
- Two layers on the moveable, lower platform



Cu	Cu	6 Pu 2 Pb	6 Pu 2 Pb	Cu	Cu
Cu	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	Cu
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
Cu	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	Cu
Cu	Cu	6 Pu 2 Pb	6 Pu 2 Pb	Cu	Cu

Top Layer

Cu	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	Cu
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
Cu	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	empty Al	Cu

Middle Layer

Cu	Cu	6 Pu 2 Pb	6 Pu 2 Pb	Cu	Cu
Cu	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	Cu
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
Cu	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	Cu
Cu	Cu	6 Pu 2 Pb	6 Pu 2 Pb	Cu	Cu

Bottom Layer

Timeline of Experiments

- HEU/Lead Experiments at NCERC
  - July 2015, 2 JAEA researchers participated
  - March 2016, 3 JAEA researchers participated
- LEU/Lead Experiments at NCERC
  - September 2016, 2 JAEA researchers participated
  - November 2016, 2 JAEA researchers participated
  - January 2017, 2 JAEA researchers participated
- Pu/Lead Experiments at NCERC
  - May 2017 2 JAEA researchers participated
- HEU/Lead Experiments at NCERC repeated
  - July 2018, 2 JAEA researchers participated

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